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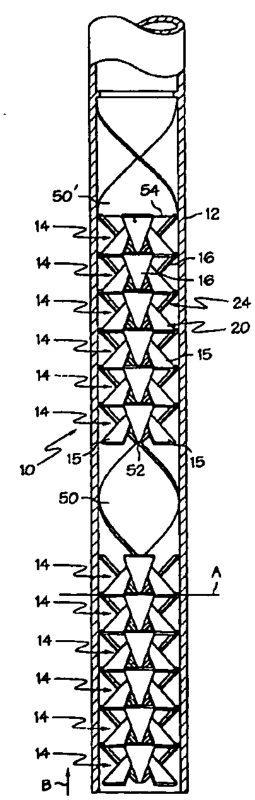
(54) Title: MULTI-COMPONENT STATIC MIXER AND METHOD OF OPERATION

(57) Abstract

A multi-component static mixer comprises (10) an upstream component (14 or 30) shaped to effect a predominantly relatively high shear mixing of the fluid in the conduit (12) and a downstream component (50) shaped to effect a predominantly low shear mixing of the fluid relative to the upstream component (14 or 30) in the conduit (12). The downstream component (50) is preferably positioned within the conduit not more than two conduit diameters downstream from the upstream component (14 or 30) whereby the upstream component breaks the fluid into droplets relatively more effectively than the downstream component (50), and the downstream component (50) distributes the droplets across the conduit cross section relatively more effectively than the upstream component (14 or 30).



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MULTI-COMPONENT STATIC MIXER AND METHOD OF OPERATION

BACKGROUND

The present invention relates to devices and methods for mixing fluids and, more particularly, to static mixers for use in conduits conveying fluids.

It is often desired to mix two or more fluids (which may be liquids, gases, or a combination of liquids and gases), or a fine particulate suspended in a fluid, to obtain an even and complete dispersion of the fluids, or fluid-particulate suspension, while the fluids or suspensions are flowing in a conduit. Static mixers are effective for mixing fluid streams in a conduit and often are preferable over turbines or other kinetic mixing devices in areas of cost, operation and maintenance, and ease of installation. Static mixers typically comprise a plurality of baffle-type elements arranged within a conduit. The fluid stream to be mixed is conveyed through the mixers, where it impinges upon the baffle-type element which directs the fluid streams in different directions, creating shear forces and/or turbulence, thereby stretching and reordering the fluid elements.

Typical single component mixer designs are comprised of a single component which is repeated. The term "component" herein means a single static mixing element of a defined shape. However, such single component static mixers have shortcomings that may appear under certain mixing conditions. For example, single component mixers may not provide efficient mixing when mixing relatively high and low viscosity fluids together. Furthermore, when an off-center or asymmetric injection is utilized, single component mixers may not disperse the injected matter effectively.

It is known that varying the shear field within a conduit may provide for superior mixing. U.S. Pat. No. 4,068,830 to Gray entitled MIXING METHOD AND SYSTEM discloses a low shear component in the form of a helical ribbon or strip located downstream of a perforated plate. However, the perforated plate disclosed in that patent serves to break up the streams of fluid into smaller streams, and does not effect mixing of the fluid streams. Accordingly, although it is desirable to vary the

shear field, static mixers of a type disclosed in the Gray patent do not effect mixing by varying the shear field in a conduit. Accordingly, there exists a need for a static mixer for use in a conduit which provides effective mixing of fluids by varying the shear field.

SUMMARY OF THE INVENTION

The present invention is a multi-component static mixer which is specially adapted to mix fluids (which may consist of liquids, a liquid and a gas, gases, and particulates suspended in a liquid), especially fluids comprised of high and low viscosity fluid streams, or a fluid stream which is asymmetrically injected into an associated conduit. The term "multi-component" herein means a mixer comprised of static mixing components of substantially differing shapes. The multi-component static mixer of the present invention subjects a fluid element to a varying shear field as it travels through the mixer. It is known that varying the shear field enhances mixing. The invention is an apparatus and method in which an upstream component, shaped to effect a predominantly high shear mixing of the fluid in the conduit, and a downstream component, shaped to effect a predominantly low shear mixing of the fluid relative to the upstream component, are combined and cooperate to provide mixing which is superior to either high or low shear static mixers.

In a preferred embodiment of the invention, the upstream component includes a plurality of generally radially extending blades, each of which is inclined in an axial direction and tapers in width from an outer periphery of the component toward the center of the conduit. The blades alternate in inclination, so that fluid volumes impinging upon adjacent blades are directed alternately radially inwardly and outwardly, thereby creating relatively high shear forces between fluid volumes flowing in alternate radial directions, which effects mixing.

In another embodiment of the invention, the upstream component includes a plurality of spaced, parallel blades inclined to the axis of the conduit and interspersed with a second plurality of spaced, parallel blades inclined to the axis of the conduit in an opposite direction. Again high shear forces are imparted to fluid

volumes when the fluid volumes impinge upon the blades and adjacent fluid volumes are directed in opposite directions.

The downstream component includes one or more strips of flat sheet material twisted to extend axially in a helical shape. Preferably, the multi-component static mixer includes a plurality of such helical components, arranged so that alternating components twist in alternate directions (i.e., clockwise followed by counterclockwise helical twists). Fluid volumes impinging upon the helical strips of the downstream component are distributed by the strips evenly across the conduit. As a result, the combination of the two components effects greater breakup of fluids, which causes subsequent homogenization of the fluid particles across the conduit. In order for such a benefit to occur, the upstream and downstream components preferably are arranged in abutting relation, or are spaced from each other no greater than two conduit diameters.

Accordingly, it is an object of the present invention to provide a multi-component static mixer and method which provides high shear values and yet provides even distribution of mixed fluid across an associated conduit; a static mixer which minimizes the pressure losses across the mixer in proportion to the degree of shear and homogenization provided; and a static mixer which is rugged, durable and relatively inexpensive to construct and install.

Other objects and advantages of the present invention will be more fully understood and appreciated by reference to the following description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side elevation of a preferred embodiment of the multi-component static mixer of the present invention shown mounted in a conduit, the conduit being shown in section;

Fig. 2 is a side elevation of an alternate embodiment of the multi-component static mixer of the present invention shown mounted in a conduit, the conduit being shown in section;

Fig. 3 is a detail side elevation of the static mixer of Fig. 1;

Fig. 4 is a detail side elevation of the static mixer of Fig.2;

Fig. 5 is a perspective view of a preferred embodiment of a high shear component of the static mixer of Fig. 1;

Fig.6 is a perspective view of an alternate embodiment of a high shear component of the static mixer of Fig. 2;

Fig. 7 is a perspective view of a preferred embodiment of a low shear component of the static mixer of the present invention;

Fig. 8 is an exploded, perspective view of the component of Fig. 5; and

Fig. 9 is a top plan view of the mixer component of Fig.5 in which an associated conduit is shown in phantom.

DETAILED DESCRIPTION

As shown in Figs. 1 and 2, multi-component static mixers of the present invention, generally designated 10, 10', are shaped to be mounted within a conduit 12. As shown in Fig. 1, the mixer 10 includes a high shear static mixing component, generally designated 14. The high shear component 14 includes a plurality of generally radially-extending, flat, blade-shaped spokes 15, 16. The spokes 15, 16 are not twisted or skewed relative to a radial plane of an associated conduit 12, but are inclined in an axial direction with respect to the conduit and taper in width from the outer periphery of the component 14 toward its center. Spokes 15 are inclined in a radially-outwardly extending, upstream direction within conduit 12, and spokes 16 are inclined in a radially-outwardly extending, downstream direction. The downstream direction is indicated by the arrows **B** in Figs. 1, and 2.

As best shown in Fig. 8, component 14 is made up of elements 20, 24, each consisting of an array of similarly-inclined spokes 15, 16, respectively, joined at their radial centers. Element 24 consists of downstream-inclined spokes 16, while element 20 consists of upstream-inclined spokes 15. The optimal range for the angle of inclination of the spokes 15, 16 is between approximately 20° and approximately 50° from a radial plane **A** (see Fig. 1), preferably between 38° and 45°.

Mixing elements 20, 24 are identical to each other in configuration, but are arranged to face in axially opposite directions in conduit 12. The elements 20, 24 are arranged in a nested relation to each other (see Fig. 1) to form each component 14, such that the upstream spokes 15 abut and are positioned in between the downstream spokes 16. Accordingly, each mixing component 14 is formed having alternate spokes 15, 16 inclined in upstream and downstream directions. The use of identical elements 20, 24 reduces manufacturing costs since only a single element need be manufactured and inventoried.

As shown in Fig. 8, each element 20, 24 has four spokes 15, 16. Elements 15, 16 may have other numbers of spokes, ranging from 3 to 12 spokes (for components having 6 to 24 spokes), without departing from the scope of the invention. In the embodiment of Figs. 1 and 5, the elements 20, 24 of each component 14 are connected to each other by weldments (not shown) at points of contact 19 (see Fig. 5) between the components.

In the mixer 10', an alternate high shear mixing-component 30 is utilized as shown in Figs. 2, 4, and 6. The alternate high shear mixing component 30 includes a lattice of intersecting fingers 32. A plurality of parallel, evenly spaced-fingers 32 form a substantially planar panel 34. Three spaced, substantially parallel panels 34 together comprise a first set of panels 36. A second set of panels 38 includes three spaced, substantially parallel panels 34'. The first and second sets of panels 36, 38 are arranged such that each panel 34 within the first set of panels 36 forms an angle with each panel 34' from the second set of panels 38 to form the mixing component 30. In this manner, each finger 32 forms an angle with a plurality of other fingers. Fluid flowing through a conduit containing mixing element 30 is redirected and reordered by the fingers 32. High shear forces are imparted to fluid volumes when the fluid volumes impinge upon the blades and adjacent fluid volumes are directed in opposite directions. Each finger 32 has an outer surface contoured to fit within the conduit.

The relatively low shear component preferably used with the present invention 10, 10' is shown in Figs. 1, 2, and 7. The low shear component includes a flat sheet of material bent to form a helix 50. The helix 50 has opposed ends 56, 58.

The ends 56, 58 of the flat sheet (not shown) are rotated relative to each other about the longitudinal axis approximately 180° to form the mixing component 50.

Each high shear component 14, 30 preferably has a K factor of between approximately 20 and 200. Each low shear component 50 preferably has a K factor of between approximately 2 and 10. The K factor is a dimensionless number which represents the pressure drop of a fluid flowing through a conduit containing a given mixing element, relative to the pressure drop for the same fluid flowing through the same conduit without any mixing components. It is to be understood that the preferred values discussed herein for K factors of the mixing components of the present invention are intended to represent K factors given laminar flow with a Reynolds number of less than 10.

In the mixers 10, 10' (see Figs. 1 and 2) the high shear components 14, 30 are positioned upstream of the associated low shear components 50. Two segments 60, 62 of the multi-component static mixers 10, 10' are shown in Figs. 3 and 4. Although the mixing components 14, 50, 30, 50, respectively, are shown in abutting relation, it is to be understood that a gap may exist between adjacent mixing components of up to two conduit diameters. With this arrangement, the upstream, high shear component 14 breaks the fluid into droplets relatively more effectively than does the downstream component 50. The downstream component 50 then distributes the droplets across the conduit cross-section more effectively than does the upstream component 14. It is to be understood that the term "droplet" as used herein means a relatively small fluid element. Furthermore, this alternating pattern of high shear and low shear mixing components (Figs. 1 and 2) may be repeated throughout the conduit to effect more complete mixing.

As shown in Figs. 1 and 2, in the mixers 10, 10', each includes a plurality of high shear components 14, 30 arranged upstream of a single low shear mixing component 50. In one such embodiment, six high shear components 14, 30 are located upstream of a single low-shear element 50. As shown in Fig. 1, it is preferable to rotate the downstream helical component 50' 90° relative to the upstream helical component 50 such that the upstream helical component trailing edge 52 is perpendicular to the downstream helical component leading edge 54.

The upstream low shear component 50 rotates the fluid in a first tangential direction, and the downstream low shear component 50' guides the fluid in the opposite tangential direction. As shown in Fig. 2, it is also preferable to rotate each alternate high shear mixing component 30 90° about the conduit axis relative to each adjacent mixing component 30.

While the forms of the apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the present invention is not limited to these precise forms and that changes may be made therein without departing from the scope of the invention.

What is claimed is:

1. For use in mixing a fluid, dissimilar fluids or a fluid with particulate matter suspended therein in a conduit, a multi-component static mixer comprising:

an upstream component shaped to effect a predominantly relatively high shear mixing of said fluid in said conduit; and

a downstream component shaped to effect a predominantly low shear mixing of said fluid relative to said upstream component in said conduit, said downstream component being positioned within said conduit not more than two conduit diameters downstream from said upstream component;

whereby said upstream component breaks said fluid into droplets relatively more effectively than said downstream component, and said downstream component distributes said droplets across said conduit cross section relatively more effectively than said upstream component.

2. The mixer of claim 1 wherein said high shear component is shaped to effect said relatively predominantly high shear mixing by generating predominantly cross flows in said fluid.

3. The mixer of claim 2 wherein said low shear component is shaped to effect said relatively predominantly low shear mixing by generating predominantly tangential flows in said fluid.

4. The mixer of claim 3 wherein said cross flows include radial flows in said fluid.

5. The static mixer of claim 4 wherein said high shear component has a K-factor between approximately 20 and 200.

6. The static mixer of claim 5 wherein said low shear component has a K-factor between approximately 2 and 10.

7. The static mixer of claim 6 wherein a second high shear unit is positioned within said conduit not more than two conduit diameters downstream from said low shear component.

8. The static mixer of claim 7 wherein each high shear component comprises of series of baffles arranged such that said fluid impinges upon and is thereby redirected by said baffles.

9. The static mixer of claim 8 wherein each said baffle is a blade comprised of generally sheet-like material.

10. The static mixer of claim 9 wherein each said blade forms an angle with said conduit axis.

11. The static mixer of claim 10 wherein each high shear component has a plurality of generally radially extending blades, each of said blades being inclined in an axial direction and tapering in width from an outer periphery of said component toward a radial center thereof, whereby fluid flowing through a conduit containing said component impinges upon said blades and is directed in a radial direction, thereby creating shear forces within said fluids to effect mixing of said fluids in said conduit.

12. The static mixer of claim 11 wherein said low shear component is a baffle having a strip of flat sheet material bent to form a helix.

13. The static mixer of claim 12 wherein each said high shear component and low shear component are arranged in abutting relation.

14. The static mixer of claim 13 wherein a second low shear unit is positioned within said conduit not more than two conduit diameters downstream from said second high shear component.

15. The static mixer of claim 14 wherein said second low shear element is rotated about the conduit axis relative to said low shear element such that said second low shear element leading edge is perpendicular to said low shear element trailing edge.

16. The static mixer of claim 13 wherein a plurality of high shear components are located upstream of a plurality of low shear components.

17. The static mixer of claim 13 wherein a plurality of high shear components are located upstream of a single low shear component.

18. The static mixer of claim 3 wherein said high shear component is comprised of two sets of mixing panels, each said set comprising three substantially parallel, spaced panels, each said panel comprising a plurality of parallel, evenly spaced fingers, wherein said sets are arranged such that each panel of said first set forms an angle with each panel of said second set to form a lattice of intersecting fingers whereby fluid flowing through a conduit said high shear component is directed in differing directions by said fingers to effect mixing therein.

19. The static mixer of claim 18 wherein said high shear component has a K-factor between approximately 20 and 200.

20. The static mixer of claim 19 wherein said low shear component has a K-factor between approximately 2 and 10.

21. The static mixer of claim 20 wherein a second high shear unit is positioned within said conduit not more than two conduit diameters downstream from said low shear component.

22. The static mixer of claim 21 wherein each high shear component comprises of series of baffles arranged such that said fluid impinges upon and is thereby redirected by said baffles.

23. The static mixer of claim 22 wherein each said baffle is a blade comprised of generally sheet-like material.

24. The static mixer of claim 23 wherein each said blade forms an angle with said conduit axis.

25. The static mixer of claim 24 wherein said low shear component is a baffle having a strip of flat sheet material bent to form a helix.

26. The static mixer of claim 25 wherein each said high shear component and low shear component are arranged in abutting relation.

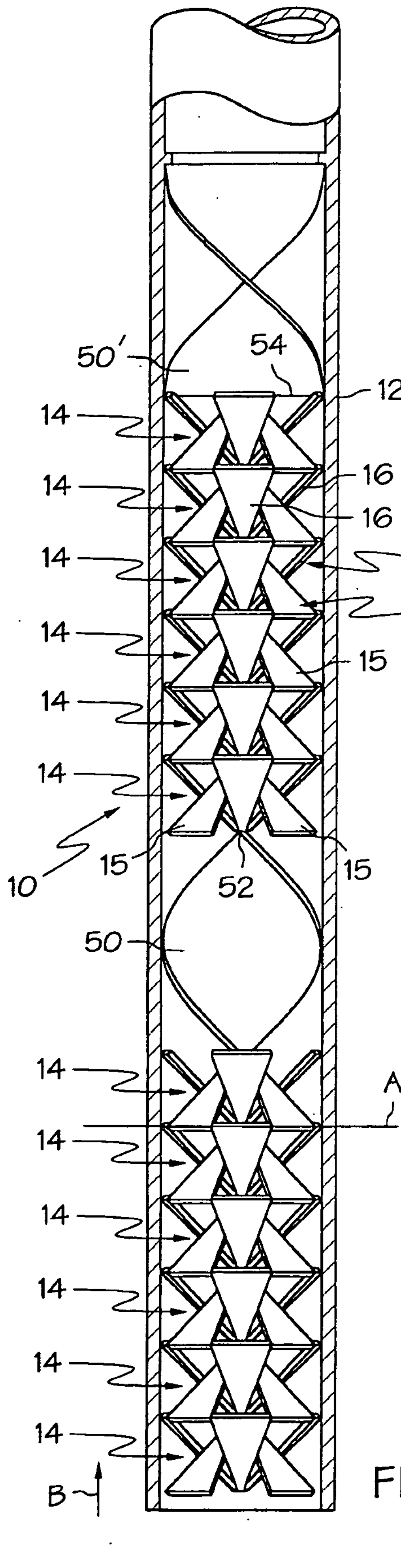
27. The static mixer of claim 26 wherein a second low shear unit is positioned within said conduit not more than two conduit diameters downstream from said second high shear component.

28. The static mixer of claim 27 wherein said second low shear element is rotated about the conduit axis relative to said low shear element such that said second low shear element leading edge is perpendicular to said low shear element trailing edge.

29. The static mixer of claim 26 wherein a plurality of high shear components are located upstream of a plurality of low shear components.

30. The static mixer of claim 26 wherein a plurality of high shear components are located upstream of a single low shear component.

31. The static mixer of claim 30 wherein each said high shear component is rotated approximately 90 degrees about said conduit axis relative to an adjacent high shear component.


50'
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10
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50
A
B

FIG. 1

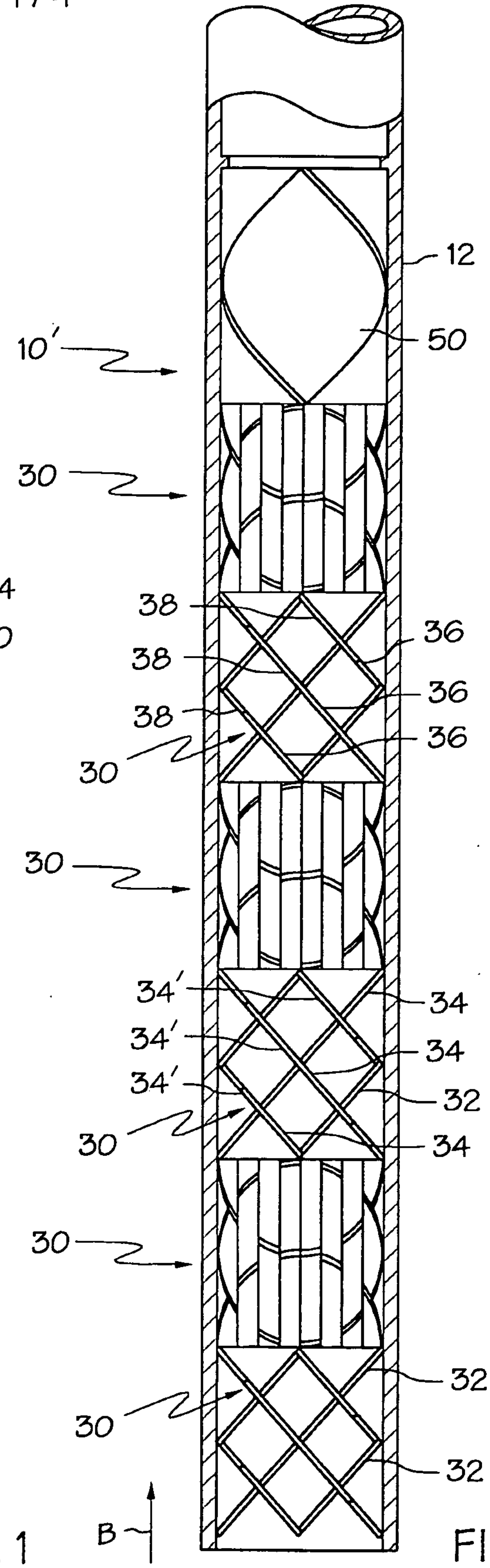
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FIG. 2

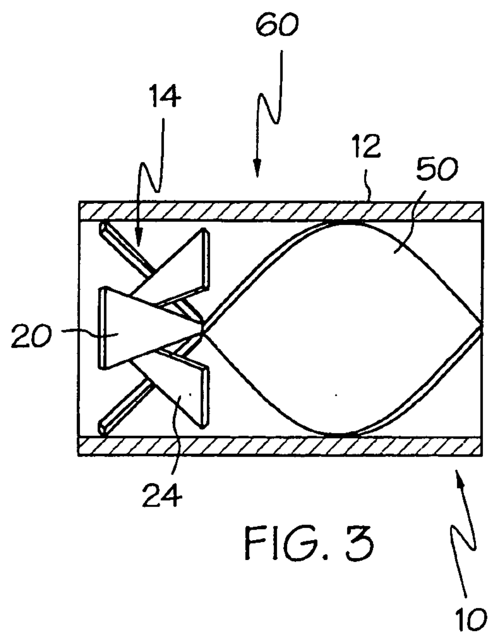


FIG. 3

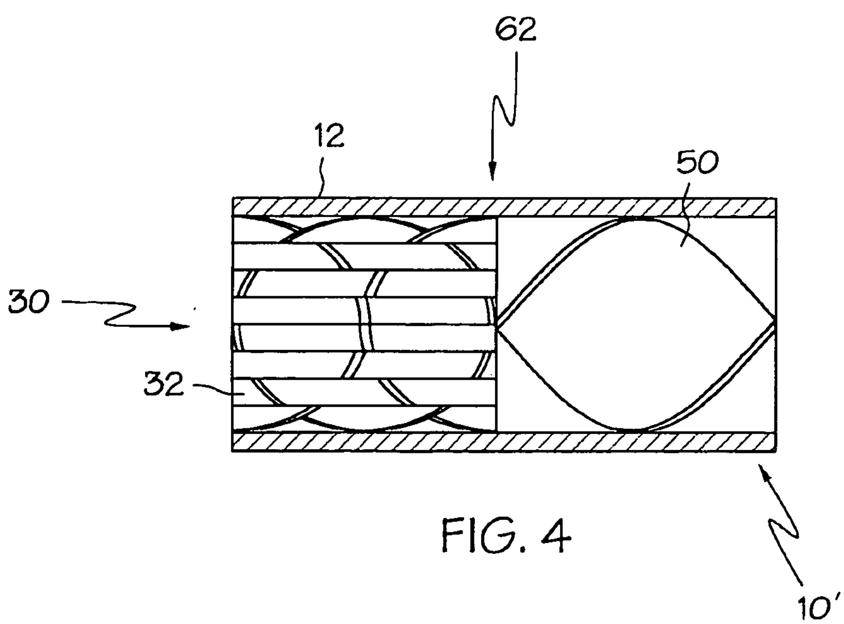


FIG. 4

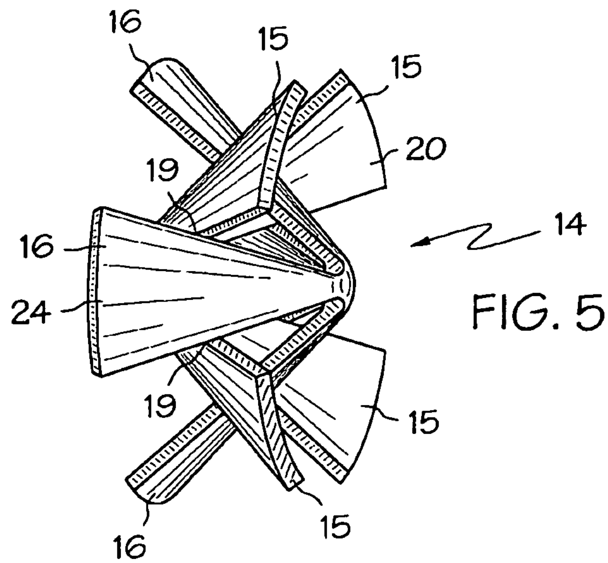
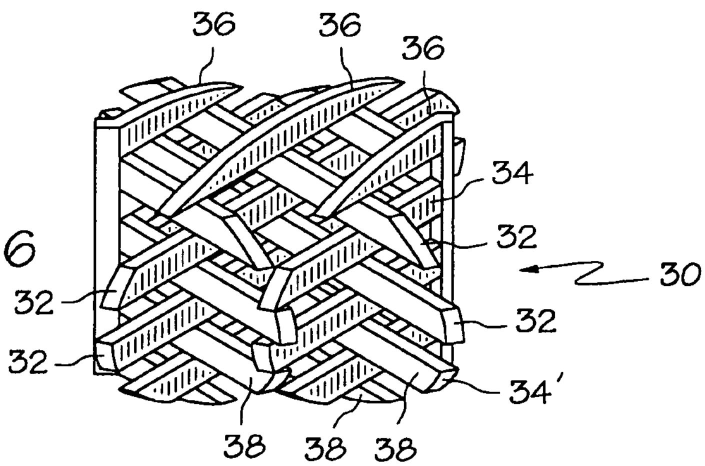


FIG. 5

FIG. 6



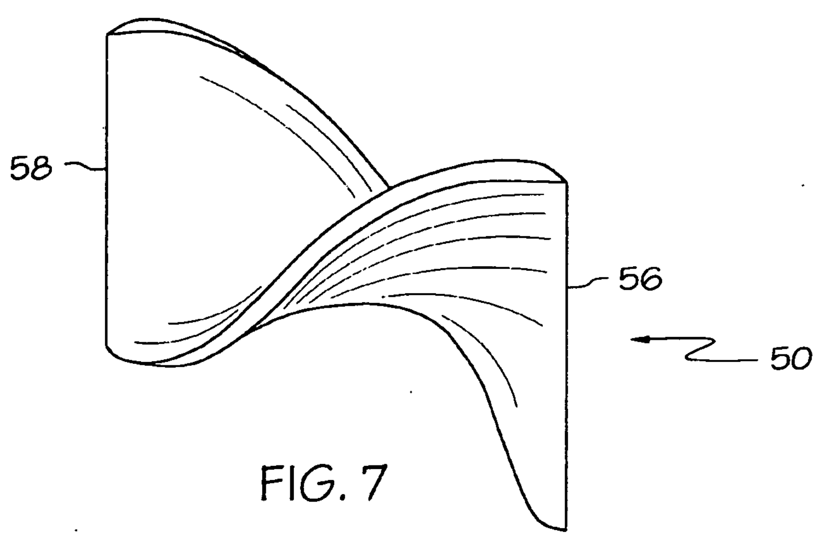


FIG. 7

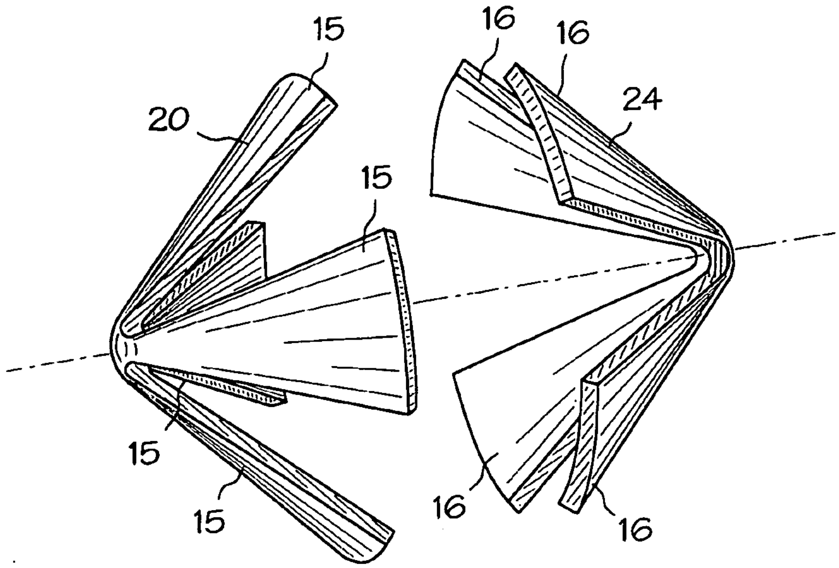


FIG. 8

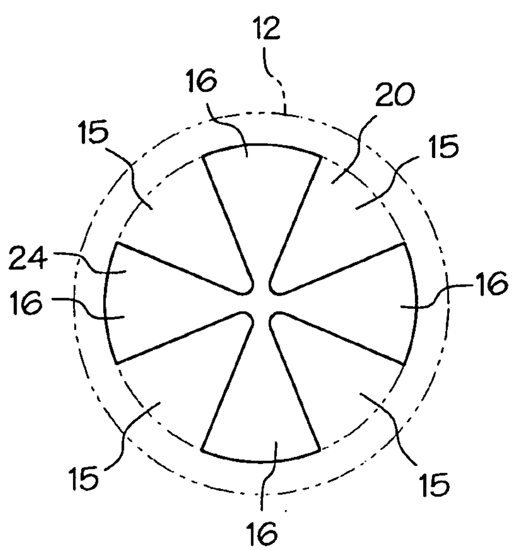


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/11901

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B01F 5/06
US CL :366/336, 337; 138/42
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 366/336, 337, 338, 339; 138/42

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,312,185 A (KOJIMA et al) 17 May 1994, see entire document.	1-4 ---- 5-8
X --- Y	GB 2 086 249 A (MITSUI TOATSU CHEM) 12 May 1982. see entire document.	1-4 ---- 5-8
X --- Y	US 3,861,652 A (CLARK et al) 21 January 1975. see entire document.	1-4 ---- 1-26
Y	WO 92/14541 A (DENA TECHNOLOGY) 03 September 1992. see entire document	1-26

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Nova'k, V et. al. HOMOGENIZATION EFFICIENCY OF MOTIONLESS MIXERS, 5th European Connference on Mixing held at Wurzburg, W. Germany, June 10-12 1985. pp. 571-579.	1-26